2006-177: ASSESSMENT RESULTS OF MULTI-INTELLIGENCE METHODS USED IN DYNAMICS

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Assessment Results of Multi-Intelligence Methods Used in Dynamics[1]

Abstract

In an effort to produce more, better graduates faster than in previous years, the University of Texas at El Paso (UTEP) integrated multi-intelligence principles into a sophomore-level dynamics class. The principal hypothesis is that students who are presented with authentic real world problems will be better equipped to solve traditional textbook problems. The belief is that confronting real problems enhances learning through the establishment of a context making the information relevant and meaningful. In this environment, students are more apt to learn and retain the information through the enhancement of student interest.

A secondary hypothesis is that real problems will stimulate student creativity and, therefore, increase the likelihood that they will be better designers. The belief is that a thorough understanding of fundamental principles allows a person to perform "mind experiments" and thereby recognize unique ways to solve problems. Intuition is a valuable asset for a designer and must be cultivated like a skill. By explaining real phenomena using fundamental principles, students will develop their creative skills. Because many students trust their intuition more than lecture materials, it becomes important to present the students with something they believe is true yet contradicts their intuition. The objective is to help students rely on their "intuition" yet show them that intuition must be developed using their knowledge of fundamental principles.

With support from the National Science Foundation, UTEP developed and implemented several "modules" in a sophomore-level dynamics class. The modules present problems that appear to be intuitively obvious yet have unexpected solutions. Students use modeling software to apply fundamental principles to explain the solutions. This paper presents the preliminary assessment of this project. The assessment instruments include the Dynamic Concept Inventory [2], grades, and attitude surveys.

Introduction

The University of Texas El Paso (UTEP) is one of the largest producers of Hispanic baccalaureate-level engineers in the continental United States. UTEP graduates can be found in the nation's top graduate schools, in the upper echelons of the nation's leading corporations and National Laboratories, and as entrepreneurs. In Hispanic Business Magazine recently, UTEP was named Number One in the Top Ten Engineering Schools for Hispanics [1]. Clearly, UTEP produces a large number of high quality baccalaureate graduates.

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The author's personal goal at UTEP is to produce even more baccalaureate graduates with even better qualifications, faster than ever before. This More, Better, Faster (MBF) goal is being pursued by a number of faculty at various levels of the curriculum.

To help standardize teaching of fundamentals, UTEP has implemented a Basic Engineering (BE) program which serves more than 60% of the undergraduate engineering students. Student success rates in the BE courses can be as low as 60%. The author has adapted methods proven at the New Mexico State University (NMSU) that address multiple intelligences and implemented them in a group learning environment to increase the success in BE courses. In particular, this paper reports the interventions used in one particular BE course (Dynamics) and gives results of several formative assessments used during the interventions.

The intervention implemented three components with team facilitation.

Component 1 – Physical demos

The first component of the intervention consists of physical demonstrations used in the classroom. The physical models are used with the following steps:

1. The student teams are asked to predict the results of a demonstration. The students must also give a reason for their answer.
2. After making predictions, the demonstration runs and typically does something unexpected.
3. After the demo, the students are asked to reevaluate their predictions and discuss them.
4. The instructor presents theory explaining the phenomenon.

Component 2 – Computer models

After the theory presentation and looking back at the demo, the instructor asks the students, "What would happen if…" "How could you make it …" and similar questions. Students explore and share ideas they develop. A collection of interactive computer models help the students explore. The models are created by the faculty and based on the physical models.

Component 3 – Textbook problems related to the phenomenon

This connects the phenomenon to material in a conventional setting. Students see, we hope, connections between textbook concepts and their relationship to physical reality.

Team Facilitation

The interventions are performed approximately once per month. During and between these interventions the class works in small teams. To facilitate the team, peer facilitators and teaching assistants (whenever they are available) help during class periods.

To provide an incentive to encourage the students to help each other, they were offered extra credit on exams. After scoring the first exam, the students were allowed to re-form their teams of three and the team composition remained fixed for the balance of the term. Extra credit for exam N was determined as follows. The team summed their points on exam (N-1) and they summed their scores on exam N. If the sum on exam N is greater than or equal to 30 plus the sum on exam (N-1) then all three students receive extra points on exam N. An example of this is a team with exam 2 scores of 100, 70 and 30 has a sum of 100+70+30 = 200. If on exam 3 they score 90, 80, and 61 their sum is 90+80+61 = 231. Since exam 3 sum is 31 points higher than exam 2 sum, each student receives the bonus on exam 3. If the bonus is 5 points (the typical value used in this study), the students receive 95, 85 and 66 on their exam 3. The method is designed to give the better students an incentive to help the weaker students. The incentive is built to prevent the strong students from simply "doing the work for" the weak student. It is the individual performance of the weak student that is critical. The instructor regularly announces to the class that he is available to help the team succeed. The objective is to make sure the strong students realize they can get the instructor to help the weaker student. Since oftentimes the weaker student may not seek help, the stronger student can encourage the weaker one to get help. The incentive virtually forces the strong students to seek out the weaker ones. If a student has a reputation among peers for being hard working, and that student has a poor grade on an exam, they become a much valued partner. This encourages all students to be positively interdependent, a key element of functioning cooperative groups.

Assessment Instruments

Since one objective of this project is to increase the success rates of students in dynamics, the class grades are monitored. To see what the students think are the reasons for their grade changes, they were asked their opinions through surveys. Students were given these surveys at the beginning, during and at the end of class. A third type of assessment was to evaluate the ability of the modules to increase the conceptual understanding in the students using the Dynamics Concept Inventory developed by the Foundation Coalition [3].

Module Details

During the discussion of the modules, keep in mind that the underlying concepts in the modules are not the author's creation. Many of these ideas have come from conversations with colleagues, background readings and similar "networking" opportunities. The author has not traced the origin of the ideas and is not claiming credit for them.

One of the first modules used in the dynamics class is the "cars" module see Figure 1. The demonstration consists of a wooden block (the figure shows two) with two wheels on one end. The block is placed on a ramp with wheels forward and again with wheels back. The left block in the figure is "wheels back" and the right one is "wheels front." The students are asked to predict which one will move down the ramp with less rotation of the block. Most students predict the wheels front car, and the most common reason given is the wood dragging behind acts like a "rudder" to steer the block. The rudder concept makes it "obvious" (to the students) that the block with the rudder in front (the left block with wheels back) is not going to go straight.

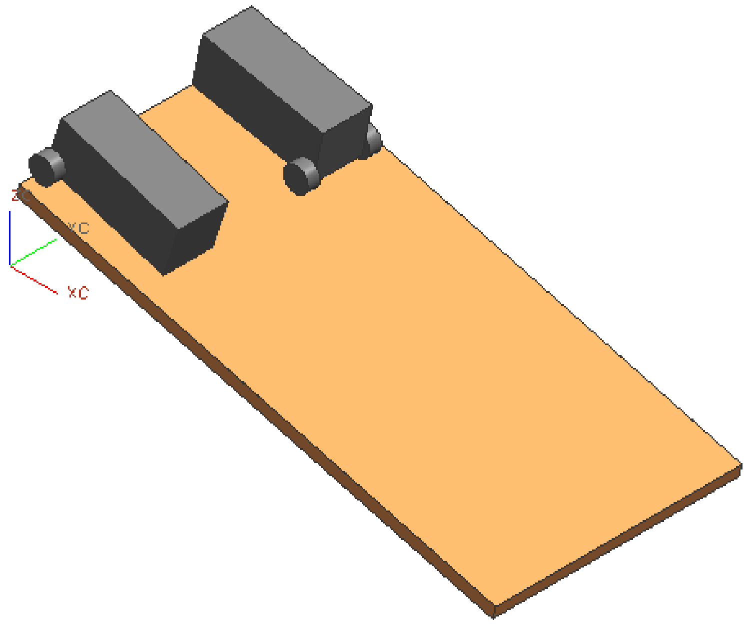

Figure 1 - Two Cars Module

When the demonstration is performed, the wheels back (the left one in the figure) goes relatively straight, and the wheels front spins about 180 degrees until it's a wheels back box and it goes straight. To view a video of this go to: http://mspace.utep.edu/leverett/cars.mpg.

When the students realize their prediction was incorrect they are asked to give an explanation. The instructor and teaching assistants facilitate as the student groups discuss possibilities. Eventually the students are led to draw freebody diagrams of the cars. Acceptable freebody diagrams are shown in Figure 2. Essentially what happens is the frictional forces from the tires are stabilizing for the wheels back and destabilizing for the wheels front. It is important to understand that the friction forces under a rolling, non-skidding, tire are predominately sideways.

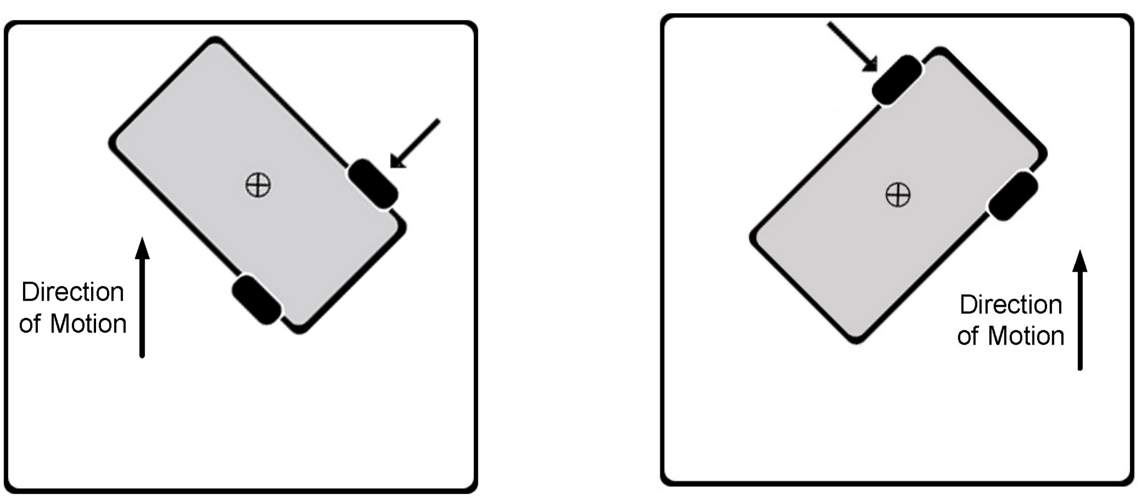

Figure 2 - Freebody Diagrams For the Cars.

Typically the students catch on once they draw the freebody diagrams. During classroom discussion, a simulation of the cars is performed via MSC.Adams. This way, when students develop a theory to explain the behavior, the simulation can be run on the computer to show the results. In practical terms, only some modifications can be implemented in real time during class; but the software is able to quickly adapt to many of the students' ideas. For example, if the students believe it has something to do with mass, you can increase or decrease the car mass quickly and run the simulation to show the students the results.

After the demonstration and simulations are finished, the students are asked how the demonstration relates to front and rear wheel drive vehicles and their stability. Many of the students have the notion that front wheel drive vehicles are more stable AND many of these same students, incorrectly, assume the wheels front represents a front wheel drive vehicle. This can produce another instance of conceptual conflict for the students because they "believe" the wheels front is a front wheel drive vehicle and they have just observed that it is unstable; opposite to what they expect. What they are confused about is that a front wheel drive vehicle is represented by the wheels back model. If you hit the accelerator hard on a front wheel drive vehicle, the front wheels spin; and, when they spin, the directional friction forces disappear on the front yet remain in the rear. As a result, the wheels front vehicle is a rear wheel drive vehicle, and the wheels back is a front wheel drive vehicle. This demonstrates that one must look beyond appearances and consider the fundamental principles that govern an object.

Next, the students are asked whether a "tail dragger" or "tricycle" landing gear on an airplane is more stable. These devices are shown in Figure 3 and Figure 4. To answer this question the students must comprehend that the main gear (the two wheels) support the aircraft load while the third wheel skids and slides due to low normal forces. This means the tail dragger has its two wheels up front and the tricycle has its two wheels in the rear. Which means … the tricycle is more stable. Ask a pilot!

After the aircraft question, the students are asked if a rocket that has fins on the bottom is more stable when it is nose-heavy or when it is tail-heavy. Again the common misconception is that the weight should be at the bottom so it can stand up. However, when the rocket flies, the stabilizing forces are at the rear (on the fins); therefore, the center of mass should be in front of the fins. This means a nose-heavy rocket is more stable in flight. This phenomenon is similar to the car scenario, yet is different in that its focus is on the placement of the center of mass rather than the forces (the wheels).

Finally, the event is concluded by asking the students why "muscle cars" are rear wheel drive. This time the freebody diagram will demonstrate that the forward acceleration "rocks" the car backward increasing the normal pressure under the drive wheels; thus, creating more friction and more forward acceleration. It is also unstable, but a race car driver wants the maximum acceleration and will be sure to drive carefully. These series of scenarios separate the students who are applying principles to the questions from those who are giving the "opposite" of their intuition. This point was made very clear by the comment of one student. When asked about the cars, the student answered correctly that the wheels back is stable. When asked how he got the answer, the student said, "It was obvious that the wheels front was the correct answer." Note that this wrong, yet the student continued, "But I know you ask tricky questions, so the right answer had to be the opposite." Obviously this student was not modifying how he approached problems, he was using his incorrect thinking and flipping his answers.

Figure 3 - Aircraft with a Tail Dragger Landing Gear Taken from the Public Domain at http://en.wikipedia.org/wiki/Image:Piper.cub.750pix.jpg.

Figure 4 - Cessna Aircraft With Tricycle Landing Gear, Copied from the Public Domain at http://en.wikipedia.org/wiki/Image:Cessna.152.g-blzh.arp.750pix.jpg

After the module is used, the students are assigned homework problems that deal with freebody diagrams or angular momentum depending on when the module is used in the semester. Depending on whether or not a project is used in the class, the students could be assigned to explore the relationships between engine torque, tire spin, stability, forward acceleration and automobile mass properties.

Due to a lack of space, the other modules will not be described in detail. They are a “bowl feeder” that shows objects “magically” climbing up a spiral ramp; a roller coaster where students, for example, predict where balls rolling on the coaster will hit the ground or where they must be released to make it through a loop; downhill skiing; and pulling a pendulum inward as it swings. All of these modules can be downloaded from: http://mspace.utep.edu/leverett/modules.

Assessment Results

Attitude surveys indicated that the students "enjoyed" the modules and demos. The performance on the concept inventory did show some improvement correlated to the module assignments.

Although there appear to be positive performance indicators and the student attitudes are generally positive, it is not clear why the methods worked and whether the positive changes will endure. Another problem area is in the support of peer facilitators. When originally funded, the project expected to pull trained facilitators from another program. Soon after the project started it became clear that the facilitator training program was defunct. As a result, the project trained a set of facilitators. This put an extra burden on project funds.

Summary of Results from the Assessments

One objective of the interventions was to increase the success rates of the students. The average success rate in Dynamics since Fall 2000 is 55.3%. The interventions have been used three semesters with success rates of 60.9%, 73.7% and 60.7%. These data show some improvement but since grades are in the control of the author, little should be drawn from them. Although the author believes standards were maintained in the grading, it is possible that unconscious bias in the grades occurred.

In addition to the grade improvements, 82% of the Fall 2004 class reported that their group worked well inside class and 65% said their group worked well outside class. Finally, 86% reported that they value group work much more now than ever before. This suggests that the student groups need the structure obtained inside class. Another encouraging factor is that 71% of the students in Fall 2004 said their group encouraged them to study harder, an indication of positive interdependence [4].

To deepen the positive interdependence [4], the instructor encouraged the students to help each other earn higher grades by offering extra credit on exams. After scoring the first exam, the students were allowed to form 3-person "exam study teams." The details of this method are outlined under Team Facilitation earlier in this paper. The results are summarized next.

Comparisons between Exams 1 and 2

- 77% scored higher on exam 2 the average increase was 21 points.
- Of the 23% scoring lower their average loss was 10 points.
- 57% scored the extra credit.
- 60% of the students attributed their group study as the most positive influence on their grade.
- 80% of the students said they planned to work more homework problems and would study early for exams, avoiding last minute preparations.
- The most common group problem described was a lack of communication.

There was a reasonably strong correlation between students who earned the extra credit and those who said the study group was effective. This indicates the students are relating study group effectiveness to earning the bonus and not necessarily to whether the group helped their understanding.

To prepare for the third exam, 80% of the students said they will continue to solve problems from the book and do all the homework problems. Since homework problems were not collected for a grade, the students are admitting they understand the importance of doing problems. Most of the students felt they needed to start studying early for their exams as opposed to last minute preparations. Acknowledging a truth is the first step to creating a change in behavior; these results are encouraging.

Comparisons between Exams 2 and 3 (reference Table 1)

- 38% scored higher on exam 3 earning an average 11 points higher.
- 51% scored an average of 16 points lower.
- No one earned the extra credit.
- 20% of the students positively attributed their group with their performance.
- On average the teams met 1-2 times for an hour and 45 minutes each week.
- The negative result showed that the students felt they needed more time to meet outside of class to study. When prompted about what this meant (since 1.75 hours/week seemed low) many responded that their family and work scheduled quite often conflicted.

A possible explanation for the poorer performance on the third exam is that the first exam grades were so low it was easy for the students to earn the extra credit on the second exam. To be able to increase a second time would require serious work and the students were probably not prepared for this. The majority of the students claimed they value group study and they felt confident while taking the exams. These results appear conflicting since the majority of the students say encouraging things about the study group yet only 20% claim the group helped them. This is another indication that students relate group effectiveness to the bonus points. Did the group directly impact an immediate reward or not?

To better understand the student's thinking, the author looked for a correlation between the students who said "I did NOT earn the extra credit" and "my group was NOT effective." These questions had a correlation coefficient of 0.63 indicating a moderately strong relationship. In other words, if the students did not earn the extra credit, you could reasonably predict they would also say the group was ineffective.

Comparisons between Exams 3 and 4 (reference Table 1)

- 59% scored higher on exam 4 earning an average 12 points higher.
- 41% scored an average of 10 points lower.
- 15% of the students earned the extra credit.
- 28% of the students positively attributed their group with their performance.
- On average the teams met 1-2 times for two hours and 39 minutes each week.

Based on the data in Table 1, by the time of the fourth exam the students felt that group work effectiveness was slipping slightly. They also felt that the group encouragement to study was also eroding. Consistent with these beliefs, the students said they did not need more time outside of class. The students also began to lose faith in the value of group study and their confidence while taking exams slipped. Although the majority of the students report attitudes we want to encourage, their gradients are negative.

Note that compared to the previous survey, fewer students believe their groups are performing well in or out of class and they do not value group study as much as before. An interesting point is that, although on the average it appears the value system of the "average" student appears to be headed away from group study, there are actually more individuals who "value group study more than ever before." Perhaps those who are becoming "believers" are strengthening their belief whereas the average person is beginning to "give up on" group study. About the same number report their group encouraging them to study but fewer of them report being the one who was the encourager. Fewer students than previous are saying they need more time out of class to meet. The average student met less and is not as concerned about it.

The correlation coefficients between students who said "I did NOT earn the extra credit" and "my group was NOT effective" is 0.69 which does not represent much change from the previous.

Based on these data, the following was concluded.

- The initial exam study groups appear to be effective; however, as time progresses, the students seem to lose faith in them. It is possible that, after the student performance boost between exams 1 and 2, the criteria for earning extra credit may be unreasonable; and the students, therefore, see little immediate value in working together. In the future, the criteria will be modified so groups that maintain their average performance earn the credit.
- Based on the data and personal conversations with the students, the poor performance gains between exams 2 and 3 may be explainable by a false sense of confidence in subject mastery and they did not work as hard to prepare for exam 3 as they did between exams 1 and 2.

Pre and Post Performance on the Dynamics Concept Inventory

To use the DCI as an assessment for the modules, the 29 questions on the DCI [2] were analyzed to determine the "fundamental concept" that it tested. Based on this analysis, the modules were developed and implemented in the class.

The DCI was given before the class and at the end of the term. Overall for the sitting being reported (additional data has not been processed as of this writing), there were 19 students taking the DCI which means there were (19)(29)=551 total questions answered. On the second sitting, the class got 17 more questions correct than on the first which means the class improved 17/551 or about 3%. This is apparently not uncommon for tests such as concept inventories.

The results in Table 2 give a slightly better picture of what is happening. Based on the analysis of the DCI content, seven DCI questions were related to the "Bowl Feeder" and "Block Cars" modules, and two questions related to the "roller coaster" module. The table shows the net gain in questions related to each module. Notice that 10 of the 17 question gains are associated with the Bowl Feeder module. The Car Module was performed early in the semester, the Roller Coaster module was "rushed" through due to time constraints, and the Bowl Feeder module had some out-of-class time associated with it. The author suspects that it was this out-of-class time that caused the increased performance on the Bowl Feeder Module questions. The conclusion is that the students need more time to think about the material. So future implementations will use more "design type" open-ended questions for students to work on as a group at the end of each module.

Table 1 - Survey Results.

	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
After Exam 3								
Strongly Agree %	25.00	21.43	25.00	28.57	35.71	42.86	25.00	21.43
Agree %	57.14	42.86	46.43	35.71	53.57	42.86	42.86	39.29
Disagree %	10.71	14.29	17.86	25.00	3.57	14.29	32.14	28.57
Strongly Disagree %	7.14	17.86	7.14	7.14	7.14	0.00	0.00	7.14
After Exam 4								
Strongly Agree %	21.88	12.50	15.63	25.00	25.00	40.63	31.25	18.75
Agree %	46.88	37.50	46.88	40.63	53.13	31.25	28.13	31.25
Disagree %	18.75	31.25	21.88	25.00	12.50	12.50	21.88	40.63
Strongly Disagree %	12.50	15.63	12.50	9.38	6.25	12.50	12.50	6.25
Q7	Group worked effectively in class							
Q8	Group worked effectively outside of class							
Q9	Encouraged group to study harder							
Q10	Was encouraged by group to study harder							
Q11	Needed more time to meet outside of class to study							
Q12	Value group study							
Q13	Value group study more than ever							
Q14	Confident while taking exam							

Table 2 - DCI Prerformance Correlated to Module.

Number of Questions	Module Name	Net Gain
7	Bowl Feeder	11
2	Roller Coaster	-1
7	Block Cars	0

Finally, results from the class attitude survey at the start of the class are shown in Figure 5. Some of the more interesting data are described here. For example question 1 and 5 say the average student is slightly concerned about the class taking too much time, but they believe they have effective time management abilities. This suggests the students "blame" the course for being difficult and time consuming.

The average student does not think working with others is a waste of time (question 2) and they are interested in helping their fellow students (question 4). Question 3 says the students want to learn effective solution methods. The students also suggest they more easily remember visual events; they like to talk about what they are learning and want solution procedures clearly defined.

Conclusions

Based on these results, the author intends to continue using the modules and will improve the implementation by creating an incentive to think about them outside of class. This could be done with a design-oriented project. The extra credit incentive will be modified so the students continue to "have hope" throughout the semester. Future work will attempt to evaluate whether or not the gains created by the modules are sustained and how the students accommodate the cognitive conflict introduced by the modules. Do the students use their faulty thinking and "flip" their answers when they feel they are being "tricked" or do they modify their concepts to accommodate the new data?

The author is interested in collaborating with other faculty who may want to use these concepts in their classes. If you would like to participate please send email to (email address will go here).

References

1. "Top 10 Engineering Schools for Hispanics", Hispanic Business Magazine, September 2005.
2. Cornwell, Phil, et al., "The Dynamics Concept Inventory", http://www.foundationcoalition.org/home/keycomponents/concept/dynamics.html , Foundation Coalition, December 2004.
3. Anon., "The Foundation Coalition", http://www.foundationcoalition.org/, December 2005.
4. Johnson, D.W., Johnson, R.T., and Smith, K.A., Active Learning: Cooperation in the College Classroom, Edina: The Interaction Book Company, 1998.

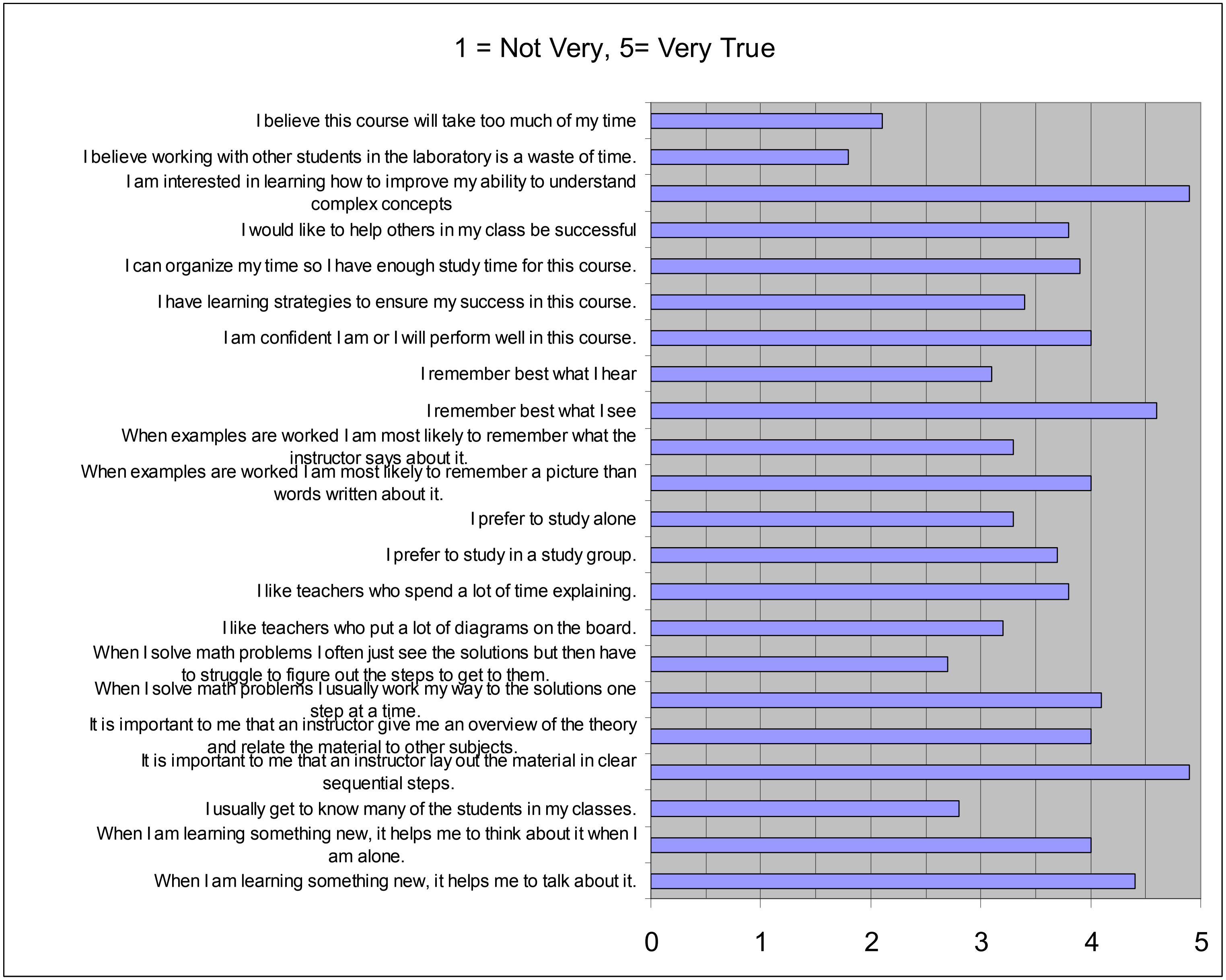

Figure 5 - Student Attitudes at the Beginning of the Class.